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CENTRAL STATION HEATING

ITS ECONOMIC FEATURES
WITH
REFERENCE TO COMMUNITY SERVICE

BY

JOHN C. WHITE

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CENTRAL STATION HEATING; ITS ECONOMIC FEATURES WITH REFERENCE TO COMMUNITY SERVICE.

By JOHN C. WHITE.

INTRODUCTION.

The Bureau of Mines offers this publication as a contribution to the literature on the conservation of fuel through more efficient utilization in power and heating plants. Especially, the paper discusses some of the possible economies that may be effected through the wider use of central heating stations, and gives data on costs and results obtained with such plants for comparison with other types.

NECESSITY OF COMPLETE UTILIZATION OF FUEL.

The conservation of national resources has lately been the subject of much discussion, and some laws have been enacted with a view primarily to preventing monopoly and control by private interests. Already much has been accomplished in the development of high efficiency in prime movers, manufacturing methods, and machinery, transportation, and hydroelectric power plants and transmission lines. These advances, however, have resulted from a commercialism that has been fatal to the highest utilization of one of our most valuable and necessary resources, coal.

Engineering attention, technical and commercial, has been occupied with the procuring of a mechanical horsepower or kilowatt hour at the switchboard for the least possible evaporative cost, regardless of the waste of heat not accounted for at that point. The limit of attainment in this direction seems now to have been reached, and yet, with units of the highest type and largest capacity, little more than 15 per cent of the heat of the fuel can be converted into a salable product as power in the form of electric energy. Many installations do not deliver more than 6 per cent of the energy of the fuel as a commercial product. A method that promises at once to increase greatly the community value of such stations in the use of coal is certainly worthy of consideration. This gain can be had by combining with steam power plants a central-station heating system.

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DEVELOPMENT OF CENTRAL-STATION SERVICE.

Many persons now in middle life can remember when the only central-station services to be had were gas and water. To these have been added the telephone, electric current, and, in some cities, heating by steam or water. When electric lighting had been developed commercially it at once became popular; nearly every hamlet now has its central station and most of these in the smaller cities and towns are extravagant in the use of fuel. In many places electric lighting was more of a fad than a necessity. People preferred electric light because it was spectacular, and they did not have to take care of oil lamps or light the gas. Companies were easily formed, and a small capital would start a plant in a community that could ill afford the service. The rates were made and the standards of service were determined by the companies; there was no public regulation of either design or operation. These conditions resulted in a one-sided development of the industry, and the possibilities of a larger use of the heat of the fuel by a combination of services giving both current and heat was practically ignored. Where, in isolated cases, such use was regarded it was based on the idea of utilizing the exhaust steam as a by-product.

HEAT A PRIME REQUISITE.

Heat is a fundamental requirement, a prime necessity for which there is no substitute; artificial light is convenient but not absolutely necessary. Furthermore, light may be had from other sources in greater volume and at less cost than from electric current. Central-station heating affords an opportunity for a great saving in the total fuel consumed by a community, at the same time for furnishing electric energy in greater quantity and at a less cost than otherwise. To make such service a success, however, some important factors must be considered and better methods and designs must be worked out. In the late seventies the first central-station heating plant was put in service at Lockport, N. Y. Since that time many others have been installed with varying degrees of success. Much has been done in the development of methods, the perfection of devices, and the working out of rate schedules and other commercial problems. In certain directions a great deal of room for improvement remains. An attempt to get information from operating companies on various features of their plants and on operation and maintenance costs was unsuccessful. Had some of these companies responded, specific data might be given instead of the assumptions and generalities on which this paper is based.

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COMPETITIVE NATURE OF SERVICE.

The test of any such project is its ability to furnish a satisfactory service for the price that may be obtained. This price is and should be competitive, but unless all of the factors entering the problem are considered at their face value the results will be misleading. One of the most important factors in the sale of steam for heating is the economy with which the steam will be used. The early method of charging for the service was based on the amount of radiation installed at an agreed rate per square foot per season. It is easy to predict the fate of the gas or electric company that had to sell its product on that basis to-day. Nevertheless, some of those heating companies survived. A later method was based on the cubic feet of space heated; this was practically the same thing in another form. The present method, and the only proper one, is to meter the condensation and to charge the consumer for the heat supplied as he is charged for any other commodity, leaving him to exercise or not the same economy in the use of the steam that he did in the use of the coal that he formerly bought.

EARLY RATES AND COSTS.

As regards selling steam on the basis of square foot or radiation, it is interesting to note that although many of the early companies charged a rate of only 20 cents a square foot for a season of 7 to 8 months, the fuel cost of energizing such radiation for a period of only 6 months (180 24-hour days) with an over-all efficiency of 50 per cent in generation and transmission, steam at atmospheric pressure and a room temperature of 70° F. would be from 10 cents to 15 cents with coal at $1 a ton. As few places get their coal at that price, it is easy to see why these heating companies failed. Many electric companies claim a cost of less than 1 cent per kilowatt hour at the switchboard; the public, however, except a few large consumers, pays three to ten times that amount for what it uses. Steam heating can never carry such an excess as that, but there must be a margin for operation, distribution, overhead costs, and profit. An attempt will be made in the following analysis to determine what difference exists between the cost of central-station service and of private heating to cover those items.

It has been shown above that the average fuel cost of supplying radiation under the conditions named will be about 10 cents to 15 cents a square foot for a season of 8 months with coal at $1 a ton. The cost can be readily computed with coal at any other price. From a series of tests at the engineering experiment station of the

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University of Illinois,[a] the plant efficiencies for such equipment with the fuels named were as follows:

Plant efficiencies for five fuels.

Fuel.	Average efficiency (per cent).
Illinois coal	48.86
Pocahontas coal	50.20
Anthracite coal	54.00
Gas-house coke	59.63
Solvay coke	61.73

The efficiencies given for Illinois coal are no doubt somewhat higher than will be maintained in practice by the average householder for an entire season. Based on the relative average heating values of the fuels named and with the efficiencies above given, the prices at which the cost of heat would be equalized to the consumer are as follows:

Data on four types of coals.

Fuel.	B. t. u. per pound as fired, average.	Heat absorbed, total value, per cent efficiency.	Cost per million B. t. u., cents.	Prices at which values equalize.
Illinois coal	12,000	5,863	8.53	$1.00
Pocahontas coal	14,750	7,400	6.75	1.26
Anthracite	12,700	6,858	7.28	1.17
Coke	12,000	7,200	7.00	1.22

Thus it appears that with Illinois coal at $1 per ton we could afford to pay $1.26 for Pocahontas, $1.17 for anthracite, and $1.22 for coke. The Illinois coal would therefore be in demand if it were not for other considerations than the cost of the heat. Some cities have smoke ordinances that make it nearly, if not quite, impossible for householders to burn Illinois coal. It also requires more labor to keep up the fires, remove ashes and clinkers, and keep the heating surfaces free from soot. All things considered, Pocahontas coal, anthracite, and coke are in demand at one and one-half to three times the cost of Illinois coal.

These differences represent charges against dirt, smoke, and excess labor. In other words, they are a contribution to cleanliness and convenience. Taking the Illinois coal at $1 a ton, with a heat value of 12,000 B. t. u. and 49 per cent average efficiency, the cost of energizing a square foot of radiation for one hundred and eighty 24-hour days will be slightly higher than for the central station mentioned above, at which the overall efficiency of generation and distribution was taken at 50 per cent. The fuel costs for the heat are therefore about the same, whether furnished by the private plant or from a central station with the same coal at the same price.

[a] Snodgrass, J. M. Fuel tests with house-heating boilers: Bull. 31, Univ. Illinois Eng. Exp. Sta. 1909, 108 pp.

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However, there are these differences: The central station can work at a higher sustained efficiency, it can produce electric current as a by-product with only a small loss of heat generated, and it eliminates all of the objectionable features of a private plant.

VALUE OF CENTRAL-STATION SERVICE.

The development of equipment and methods of operation in the boiler room of the modern power plant leave little to be accomplished there. Soft coal may be had under contract in Wisconsin at prices ranging from $2.50 to $3.50 a ton on track. It can be burned at an overall efficiency of more than 70 per cent and the product is heat with steam as the medium of transmission. Served in this manner through a distribution system, the heat has a value equivalent to the total cost of all items included in the operation of a private plant plus a considerable allowance for greater convenience and perfect cleanliness, and it should be so estimated in all computations on which costs and rates are based. Whether or not it is exhaust steam in whole or in part has no bearing on the case; any allowance in that direction should affect the price of current and not the cost or the value of the steam. The steam should be considered the prime requisite, with any output of incidentally derived current as the by-product; it will then stand or fall on its own merits, which is the only substantial measurement of its value. The reasons on which this argument is based will be given later.

PRICE OF CLEANLINESS.

As regards the generation and transmission costs and margins, with coal at $3 a ton and an overall efficiency in the plant of 70 per cent, the steam can be delivered at a fuel cost of approximately 30 cents a square foot of radiation served. This allows 20 per cent for loss in transmission, a figure considerably higher than that found in practice, as evidenced by a report in Bulletin 40[a] of the Bureau of Mines, where this loss is given as 4 to 12 per cent. The same coal will cost the private user about $4 a ton delivered at his premises, and his fuel cost for the same amount of heat will therefore be not less than 40 cents. But he still has the smoke, dirt, and labor inseparable from the use of soft coal in such equipment as he uses. How much is the elimination of these objectionable items worth? Based on the relative costs of the soft coal and those substitutes—anthracite and coke—which most nearly accomplish the desired end, so far as smoke and dirt are concerned, it is worth from 100

[a] Randall, D. T., and Weeks, H. W., The smokeless combustion of coal in boiler furnaces, with a chapter on central heating plants, 1912, pp. 181–182.

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to 150 per cent more than the estimated cost of the heat as computed at 40 cents, making the real value 80 cents to $1.20 a square foot a season. These values may seem high, but when the economy that is practiced in the use of hard coal at $8 to $9 per ton is considered, they are probably not far from correct. Storm windows are in evidence at the first frost, ventilation is sacrificed, and no space is heated that is not absolutely needed.

COMPARISON OF COSTS OF SERVICE FROM PRIVATE PLANT AND CENTRAL STATION.

The use of the fuels of higher grade eliminates nearly all of the smoke, part of the dirt, and some of the labor; but it is still necessary to provide and maintain a furnace and furnace room, and coal storage, to buy coal, haul out ashes, and do the firing and cleaning. These items may be estimated to cost approximately 50 per cent of the value of the soft coal burned. Assuming that the investment is already made in the private plant, we can make no charge against that except for repairs; these can be neglected, as can also any charge for space occupied by equipment, coal, or ashes. Adding the 50 per cent, or 20 cents a square foot as determined above, to each of the costs for the various fuels, gives us rates of 60 cents, $1, and $1.40, respectively, for Illinois coal, anthracite, and coke.

The central station can deliver the heat for a fuel cost of 30 cents, thus leaving margins of 30 cents, 70 cents, and $1.10 to cover labor, maintenance, overhead charges, transmission, and profits. In addition the station has eliminated every objectionable feature of the service and made it a convenience instead of a nuisance. It is a fact worthy of note that central-station heating plants are most numerous where coal is abundant and cheap, as in Pennsylvania, Ohio, Indiana, and Illinois. This confirms the deductions to be made from the preceding statements, namely, that the elimination of the smoke, dirt, and disagreeable labor are of more value in some cases than the fuel cost of the heat. In the localities cited this elimination is essentially what the consumer is paying for. The fuel is so convenient and cheap that the central station can offer no inducements in the way of economy and must make its campaign for consumers on the basis of better service and the elimination of all objectionable features.

As stated before, a number of the old companies did survive the period of 20-cent rates; coal was cheap and they had a considerable quantity of exhaust steam which they discounted in making their rates, and the product of the steam—electric current—was sold at a good profit. Still, it is remarkable that they could exist with the fuel cost approximately 12 cents a square foot a season and only a margin of 8 cents left to cover all investment and operation charges.

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ANOTHER METHOD OF COMPUTING COSTS.

If the problem be viewed from another angle, the cost of evaporating a given quantity of water in the large public-service plant as against the small private plant may furnish a better basis for comparison. With Illinois coal at $1 a ton the fuel cost of evaporating 1,000 pounds of water (generating 1,000 pounds of steam), should not exceed 7 cents, and in a well-designed and carefully operated plant may be as low as 6 cents. The other costs will increase this figure to about 10 cents, and with coal at $3 a ton the total cost will be about 25 cents. The private consumer can not evaporate the water any more cheaply, even with coal at the same price, and as he will have to pay more for his coal, the cost to him of evaporation will be more. Furthermore, when he only requires a little heat his efficiencies drop very low and his losses are correspondingly great.

In the former estimate of the cost of supplying 1 square foot of radiation for 180 days, a rate of emission of 2.5 B. t. u. per square foot of surface and per degree difference of temperature per hour was used. This rate shows that 1,500,000 B. t. u. will be required to energize 1 square foot of radiation for the 180-day period. In evaporating 1,000 pounds of water there will be a heat transfer of approximately 1,000,000 B. t. u., at a cost of 25 cents with coal at $3 per ton. From these figures it evidently will cost 38 to 40 cents to evaporate the water for each square foot of radiation supplied. To this figure must be added all investment, operation, and other charges on the plant and distribution system. These can only be approximated in a general estimate, but they will probably equal the fuel cost, thus bringing the total up to 75 cents or 80 cents a square foot a season. The reader should bear in mind that in the computations made on the quantity of heat emitted the radiation was assumed to be active for the entire period. This will not necessarily hold in practice, and less heat will be required than the amount charged in this discussion. It makes little difference, however, as the lessening will be of about the same amount whether the radiation system is heated privately or from a public-service main.

RATES FOR STEAM.

From schedules of rates in 28 cities of 25,000 to 40,000 inhabitants, covering many of the Middle States and ranging in latitude from Michigan and New York to Georgia and Alabama, the highest minimum is $1.50 per 1,000 pounds of steam at Peoria, Ill., and the lowest for maximum consumption is $0.3105, at St. Joseph, Mo. The lowest minimum consumption rate is 54 cents at Penn Yan and Geneva, N. Y., and the rate at these points for maximum consumption is 46.35 cents. The average minimum and maximum rates for

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the 28 cities, on quantities of 4,000 pounds or less and 300,000 pounds or more per month, are 76.40 cents and 45.33 cents, respectively.

Although a study of these rates shows an entire lack of uniformity in the methods of their deduction, the averages given confirm in general the costs established herein for furnishing 1,000 pounds of steam. In about half of the schedules mentioned there is a demand charge of $3 a month minimum on all buildings having a capacity of 25,000 cubic feet of space or less, and of 12 cents per 1,000 cubic feet on all buildings having more than 25,000 cubic feet.

ECONOMY IN USE OF STEAM.

From the foregoing statement it is evident that economy in the use of steam from a central station is just as important as in the use of the coal burned privately. Will the consumer practice such economy? Under meter rates it may be assumed he will; under flat rates he will not.

The quantity of heat necessary to supply 1 square foot of radiation for a season is probably less than the estimate already given (p. 8) in this paper. Although the heating season is one to two months longer than the period named, there are many days in the early fall and late spring when little or no heat is required. At such times the consumer can reduce his active radiation to any amount desired with less trouble than he can allow his fire to go out and be rekindled. He can also have a little heat in the morning and shut it off for the rest of the day if he desires. A proper demand charge will protect the central station at such times. The station has a decided advantage also, in that the boiler capacity in service can be adjusted to the load and maximum efficiency can thus be maintained.

As with some electric schedules, many rates for steam throw a burden on the small consumer by forcing him to help pay for the large consumer's service. In the case of steam no consumer should be given service for less than a profitable rate. In rates for electric service there is some justification for the apparent discrimination as between the large and the small consumers. The former may make their heaviest demands at times when the load is otherwise small and thus increase the station load factor. In a central-station steam plant the load varies little during the entire day; the demands for steam go up and down with changes of wind and temperature. Such changes are gradual and give ample time for controlling the operation of the plant so that the highest possible economy can be realized. Daily peaks are almost negligible.

EXHAUST STEAM.

Thus far exhaust steam has not been considered, because there is no difference between it and live steam at the same pressure, and

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any exhaust steam that may become available for distribution costs just as much and it is worth just as much for heating as though a part of its original energy had not been converted into useful work. In a combined plant the product resulting from such conversion—usually electric current—should be considered the by-product.

Where the heating load is large enough to entirely submerge the power load, there will be no peaks in the boiler room through variations in the latter. The power requirements may vary from zero to maximum and the firemen will not know it unless some one tells them or they consult the records. When the engines are exhausting their maximum into the heating system, the reducing valves will automatically cut the supply of live steam to the required amount; when the power load is a minimum they will open and supply live steam to meet the requirements.

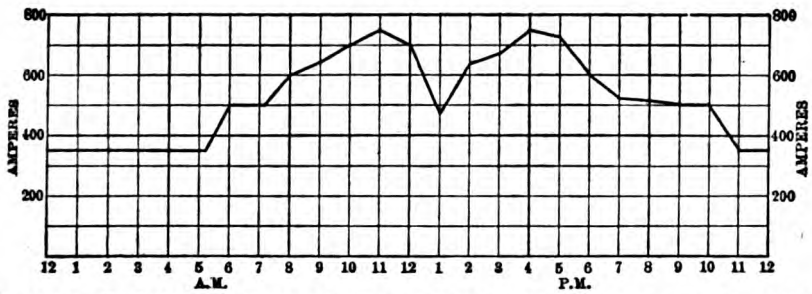

FIGURE 1.—Typical daily power-load curve, December, State capitol power plant, Madison, Wis.

The following curves, from the records of the State capitol power plant at Madison, Wis., will make this clear. Figure 1 is a typical daily, power-load curve; it shows a variation of over 100 per cent in current output. Figure 2 is a daily feed-water chart; no evidence of the variation in the power load is discernible in it. Figure 3 is a feed-water record of the day before that of figure 2. This record shows the effect on the feed-water rate of changing from simple noncondensing engines to compound condensing engines. The heat thus wasted to the sewer costs about $15 a day of 24 hours for each kilowatt output. The engine is a compound condensing Corliss with an economy of about 14 pounds of steam per indicated horsepower per hour. Figure 4 is a curve showing the relation of coal burned to temperatures. Ordinarily no heating is done from June 15 to September 15. The fuel used during that period is all chargeable to electric service, pumping and steam for other uses. Compound condensing engines are used when no heating is required.

These graphical data mentioned are from the records for 1911. Figures 5 and 6 are from the records for December 29 and 30, 1917, the charts being removed at 7 a. m. on those dates. It will be noted

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that the loads are much heavier and that the quantities are therefore greater, the reason being that in 1911 only part of the new capitol at Madison was in use, whereas in 1917 the building was completed and full service was being given.

Figure 5 was obtained to show the effect of the ventilating equipment on the heating loads. The fans were running from 6 a. m. to 12 m., when they were stopped. The feed-water rate dropped about 5,000 pounds an hour at that time. The electrical load also dropped

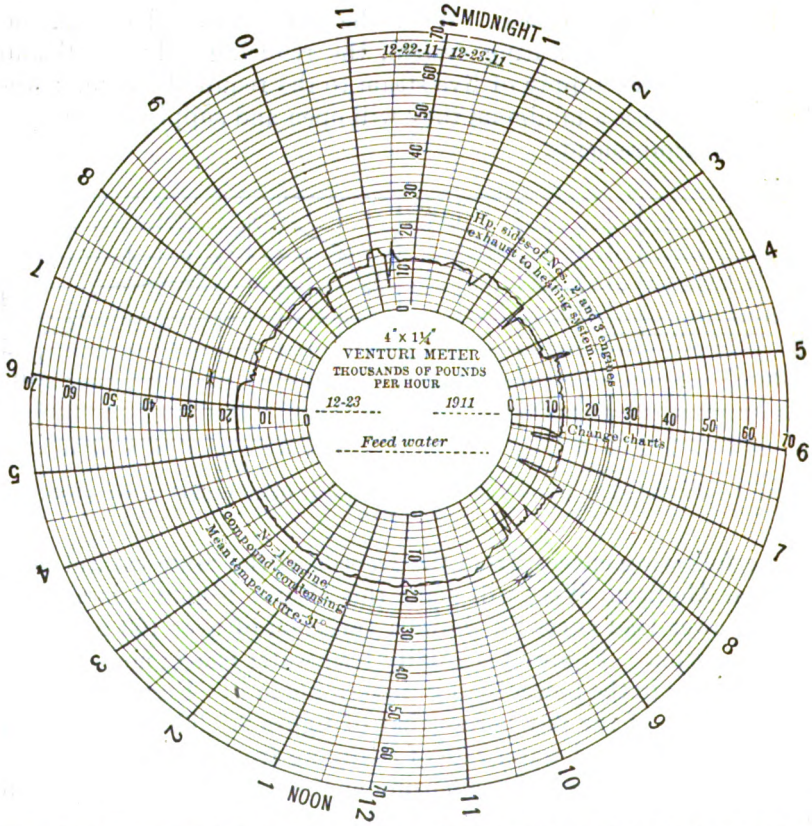

FIGURE 2.—An average daily feed-water record, December, Wisconsin capitol power plant.

about 500 amperes because of the fan motors being cut out and because of the normal noon-time drop due to other reasons. Later on it increased again until closing time at 5 p. m. The feed-water rate shows little difference accountable through any change in the power load, the latter being submerged at all times; in addition to the exhaust steam available, live steam was required for the heating load during the entire 24 hours.

Figure 6 is the record for the following day and confirms the previous record, the only essential difference being that it was Satur-

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day and most of the offices were closed in the afternoon, thus reducing the power requirements. The temperatures for the two days were practically the same. From 150 to 250 amperes of the electrical load from 7 a. m. to 9 p. m. is used for cooking, heating water, etc., in the capitol restaurant. This heat for the restaurant could be supplied much more cheaply by other means, and, although the consequent fuel expense is negligible in severe weather, it becomes a direct

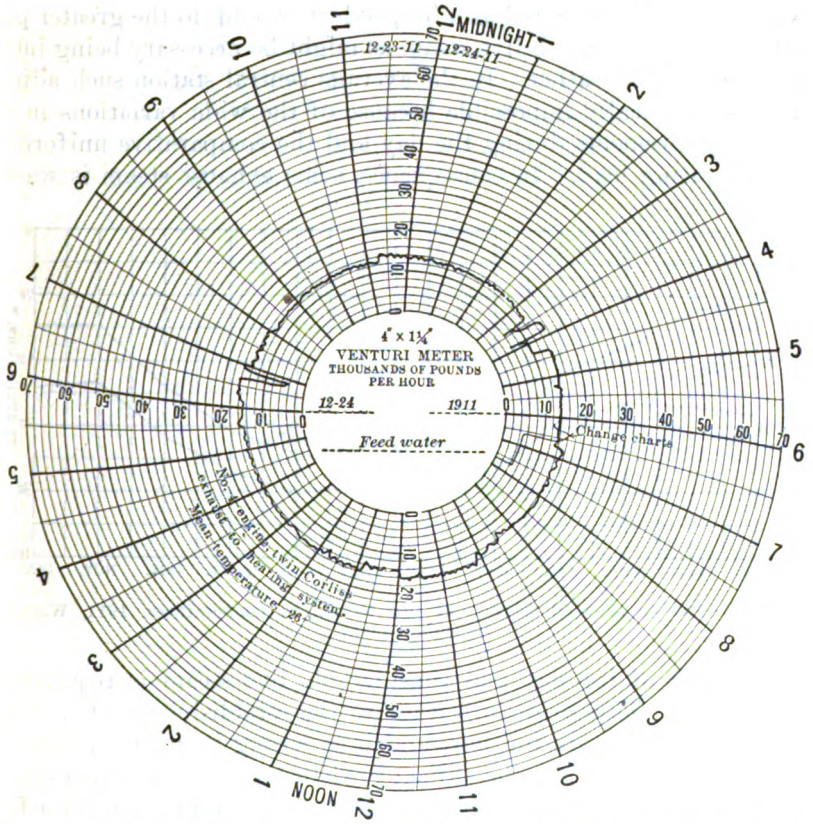

FIGURE 3.—Feed-water record; shows effect of changing from simple noncondensing to compound condensing engines, Wisconsin capitol plant.

expense when the heating load is light. Where steam and gas are available the use of electric current to produce heat should be discouraged, except for special requirements.

CORRELATION OF LOADS.

The relations of loads, as disclosed by these records, have an important bearing on the subject of central-station heating. They show that when the heating load is made large enough to give constant conditions in the boiler room, the efficiency there is decidedly

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increased and the power output becomes a matter of secondary importance as far as cost of operation is concerned. Although for commercial reasons, the keeping of the station load factor for power as high as possible is desirable, peaks and variations of any magnitude within the range of the boiler capacity can be handled with a minimum of trouble and expense.

The early efforts—and, perhaps, those of the present—sought to adjust the loads in a combined power and heating plant so that the exhaust steam, considered as a by-product, would do the greater part of the heating, as much live steam as might be necessary being introduced in severe weather. In the average central station such adjustment is practically impossible because of the wide variations in the power requirements during the day and the comparative uniformity of the heating load. In consequence, some exhaust steam is wasted

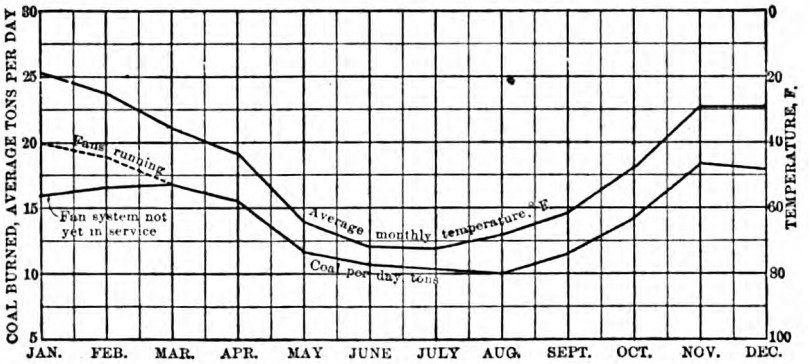

FIGURE 4.—Curves showing relation of fuel burned to temperatures, 1911, Wisconsin capitol plant.

during part of the day and considerable live steam is required at other times. This procedure leads to the establishment of heating-service rates that are too low, and it is wrong in principle for the reason that it discounts the value of exhaust steam. Fortunately, in some of the successful plants the heating load crept up until a favorable relation existed and, had the rates been equitable, a much better showing could have been made. Where the service is good it is not difficult to book all of the business, or a satisfactory part of it, along the mains. The central station that can supply both heat and current stands a much better chance of displacing the isolated plant than the one that can bid for the current only.

In cities of medium size the same boiler capacity that can supply three to four blocks with current will heat only about one. This fact should make it comparatively easy to take on a suitable heating load within easy distance of the plant where the latter is situated favorably with regard to the district served. By a suitable heating

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load is meant one in which the power ceases to be a factor so far as the boiler requirements are concerned. As regards steam that has passed from a higher to a lower pressure by doing useful work in an engine, it is in a way analogous to water that is used for irrigation, navigation, or any other purpose after it has driven the wheels of a power plant. The quantity of water remains the same, and if it still has sufficient head or depth it will irrigate as much land or float as

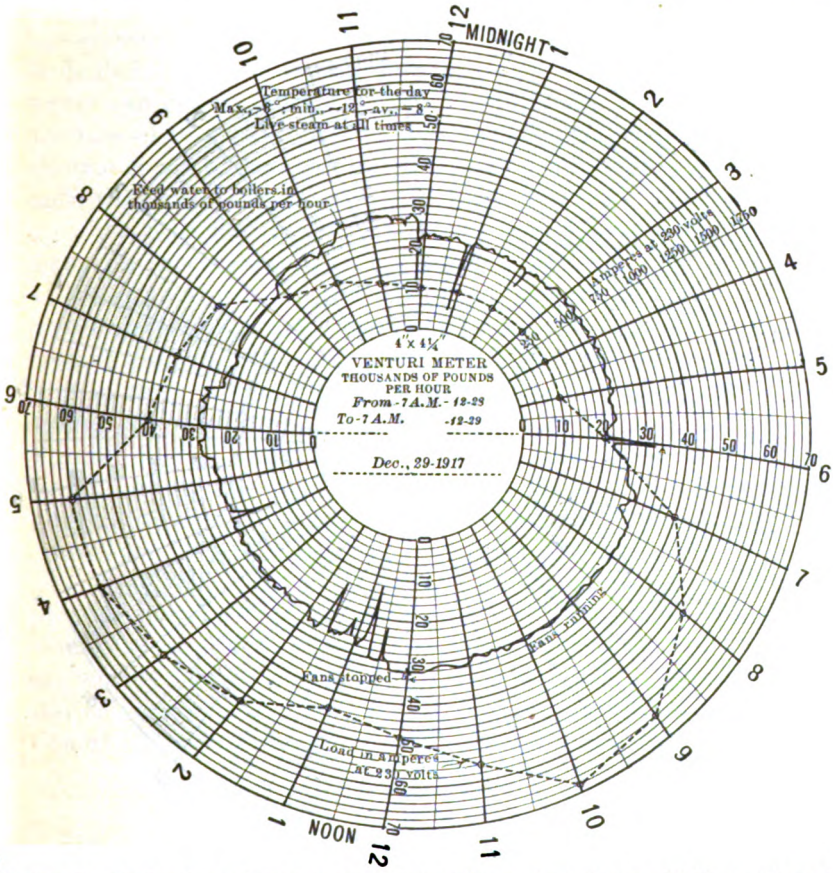

FIGURE 5.—Feed-water and load record; shows effects of running ventilating equipment, Wisconsin capitol plant.

large a boat. The steam, after it has passed the engines, will do nearly as much heating as it would before. The current generated may vary from zero to maximum, with only a trifling increase in the quantity of fuel required.

For this reason the steam should be considered the prime requisite and any current produced should be considered the by-product. The latter will be cheapened somewhat by the process and a correspondingly greater number of people will be benefited by the combination. Also, the fuel will be utilized more efficiently.

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WATER POWERS AS SOURCES OF HEAT.

It has been suggested that the development of the water powers of Wisconsin would furnish a perpetual substitute for coal in producing current for industrial and domestic use and for heating. As regards power the suggestion is true to a certain degree, but as regards heat it is not. Probably no one familiar with the subject ever attached much value to the water powers for heating other than

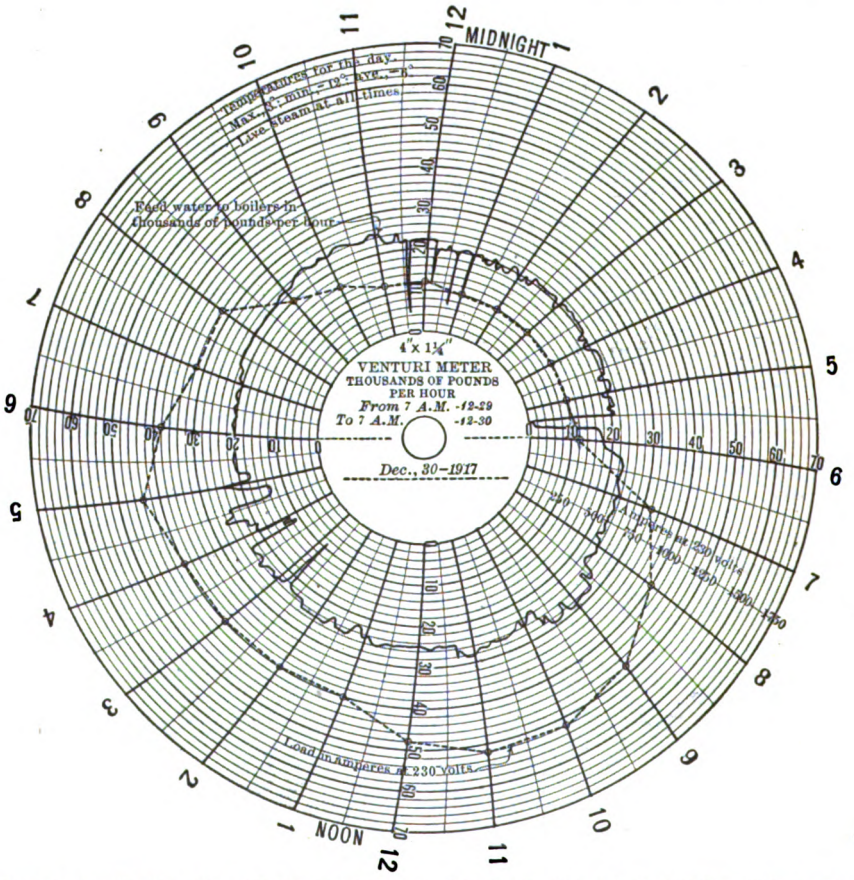

FIGURE 6.—Feed-water and load record, for day that was a half holiday, Wisconsin capitol plant.

in furnaces and in electrolytic processes. To the lay mind it may appear possible to do considerable heating from such water power. A brief consideration of the matter may be of interest.

On a severe day in the winter about 10,000 pounds of coal with an average value of 13,000 B. t. u. is burned each hour at the University of Wisconsin heating plant. This consumption of coal repre-

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sents the liberation of about 130,000,000 heat units. Hence at 50 per cent overall efficiency 65,000,000 heat units were needed to warm the buildings. From a 20,000-horsepower hydroelectric plant only about 51,000,000 heat units could be furnished, and, these if used at 100 per cent efficiency would not be able to heat the one institution.

As to the cost of the two methods, the heat of the 5 tons of coal costs about $20 generated and delivered to the buildings; the 20,000-horsepower hours from the water-power plant, at one-half cent per horsepower hour, would cost $100. Its procurement at that figure is doubtful, as it is worth more for other use. The reason electric power can not do much heating is because 778 foot-pounds of work are needed to produce one unit of heat. It has been estimated that electric current from our water powers can not be used for heating until the price of soft coal has arisen to about $20 per ton, and even then the heat that could be obtained would not be enough heat to make its procurement worth while. Applied to industrial use and as a motive power for transportation, the current from our water-power developments is worth many times what it would be in any heating project. However, many industrial plants require so much heat in their processes that a steam plant is necessary whatever the source of power. A survey of a number of paper mills, wood-working plants, and other industries has shown that no saving could be effected by the purchase of outside current at the lowest rates possible to obtain. The engineers of one important factory, by a careful analysis of all costs, determined that outside current would have to be supplied at 0.7 cent a kilowatt hour in order for the plant to come out even on the deal. This was a careful and competent investigation, without bias in either direction, and the results are worthy of note because they would apply to a combined central-station service as a public utility, being modified only by the addition of a distribution system and the handling of the business.

HOT WATER AS HEATING MEDIUM.

Steam is most generally used as the medium for conveying the heat to the consumers, although hot water has its advocates, and in some ways it has advantages. Where hot-water radiation has already been installed it is a simple matter to put in a small heater and use the steam for heating the water instead of heating it directly by a coal fire. Nearly any kind of steam or hot-water system that a consumer may have can be satisfactorily operated from the central station mains by using the necessary devices for pressure regulation and control. All installations should have thermostatic regulation if the best economy is to be maintained.

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GOOD ENGINEERING NECESSARY.

The design, materials of construction, and the methods of operation of district steam-heating plants require careful consideration by competent engineers to insure the success of each installation. Generally, the pipe lines have been iron or steel pipe, several times heavier and stronger than necessary for the pressure carried but failing rapidly by corrosion. It is a false economy to use material not permanently resistant to destructive agents. The pipe is only one item of the underground expense, and means should be devised of making it durable. The best is the cheapest where a long life with low maintenance cost is necessary to success.

The practice has been to lay the mains in the streets or alleys. This is desirable wherever possible. However, in mine and mill work the mains are frequently carried considerable distances overhead. Tunnels are convenient, but their cost is generally prohibitive except in the largest cities. Our city planning should include better provision for underground services than is to be had at present. The streets are practically the same in width and surface arrangement that they were 50 years ago, when gas and water were the only utilities requiring space; at present there are some six or more besides the sewers, and the number will increase.

RECOMMENDATIONS.

Based on the foregoing discussion it would appear advantageous to—

Select plant locations favorable to the district to be served.

Adopt more permanent construction materials and improved designs.

Submerge the power load entirely at all times during the heating season.

Put all consumers on meter rates with an equitable demand charge.

Run compound engines, or exhaust the turbines tandem to simple engines during the summer months.

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